

1989005473

52-75

N89 - 14844

175148

78

HELIUM-3 BLANKETS FOR TRITIUM BREEDING IN FUSION REACTORS

**Don Steiner, Mark Embrechts, Georgios Varsamis,
and Roger Vesey
Dept. of Nuclear Engineering and Engineering Physics
Rensselaer Polytechnic Institute
Troy, NY 12181**

and

**Paul Gierszewski
Canadian Fusion Fuels Technology Project**

RY 93523

CF 448284

OBSERVATIONS

- RESOURCE CONSIDERATIONS HAVE LIMITED D-T FUSION REACTOR BLANKET STUDIES TO LITHIUM-BASED SYSTEMS
- WHILE ACCEPTABLE LITHIUM-BASED BLANKET DESIGNS HAVE BEEN DEVELOPED SAFETY & ENGINEERING CONCERNS ARE ASSOCIATED WITH THE USE OF LITHIUM
- THE BEST SAFETY FEATURES ARE GENERALLY ATTRIBUTED TO BLANKETS EMPLOYING HELIUM AS COOLANT
- IT WOULD BE DESIRABLE TO DEVELOP A TRITIUM BREEDING OPTION WHICH RETAINS HELIUM AS COOLANT AND ELIMINATES LITHIUM CONCERNS
- A HELIUM-3 (BREEDER)/HELIUM-4 (COOLANT) BLANKET OFFERS PROMISE FOR ENHANCED SAFETY & ENGINEERING CHARACTERISTICS

ESECOM RESULTS

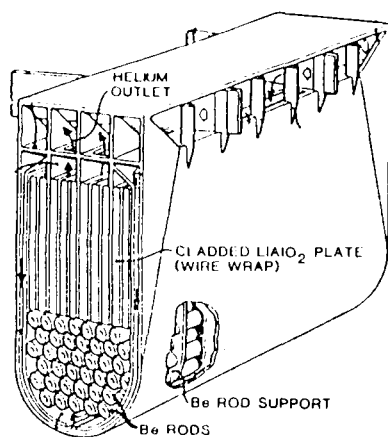
FUSION TECHNOLOGY/JAN., 1988

Case	Nominal LSA	COE (mill/kW·h)
1. V-Li/TOK	3	49.7
2. RAF-He/TOK	2	42.6
3. RAF-PbLi/RFP	4	37.7
4. V-Li/RFP	4	37.3
5. SiC-He/TOK	1	40.3
6. V-Flibe/TOK	2	42.9
7. V-MHD/TOK	4	35.4
8. V-D ³ He/TOK	2	41.3
9. RAF-Li/HYB	4	
Stand alone		63.7
With MHTGR clients		40.3
10. SS-He/HYB	4	
Stand alone		55.8
With MHTGR clients		39.8

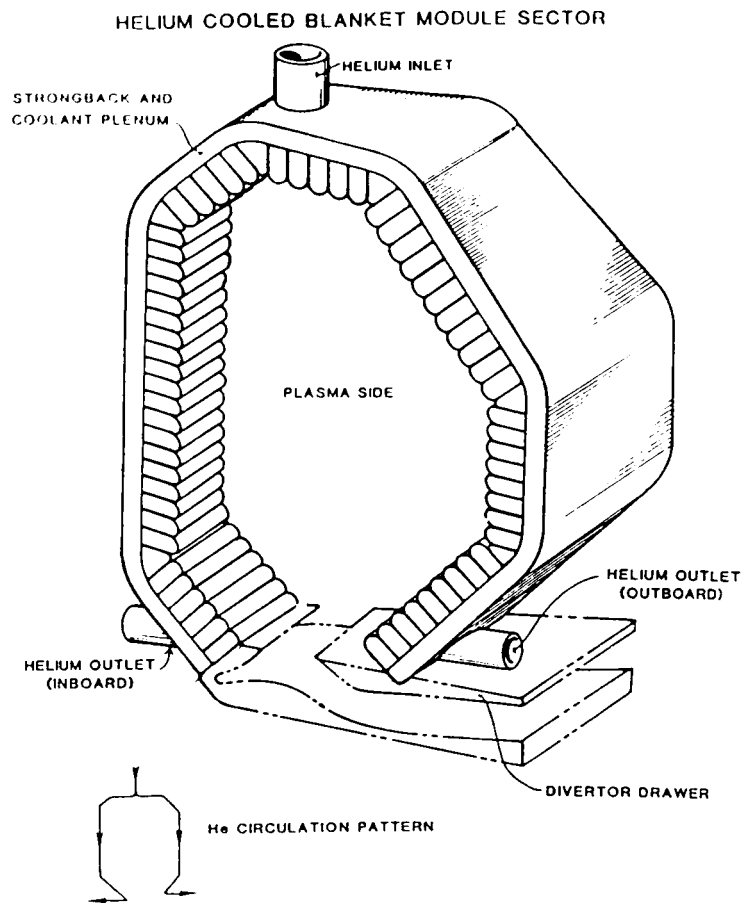
GENERAL FEATURES OF CONCEPT

- USE HELIUM-3 TO BREED TRITIUM
[large $\sigma(n,T)$ of ^3He]
- BLANKET COOLANT WOULD BE HELIUM-4
 - OPERATING AT ABOUT 5 MPa
 - 100 - 300 C (NEAR TERM)
 - 250 - 500 C (COMMERCIAL)
- BLANKET STRUCTURE WOULD BE CONVENTIONAL (e.g. STAINLESS STEEL) OR ADVANCED (e.g. SiC)
- BERYLLIUM WOULD BE USED FOR NEUTRON MULTIPLICATION [large $\sigma(n,2n)$]
- HELIUM-3 CONTAINED IN A LOOP SEPARATE FROM HELIUM-4 LOOP AND FLOWS WITHIN THE BERYLLIUM, ALSO ACTING AS A PURGE FOR BERYLLIUM-BRED TRITIUM
- CONCEPT FEATURES SIMILAR TO THOSE OF A He/SB BLANKET WITH EXCEPTION THAT ISSUES ASSOCIATED WITH THE SB ARE ELIMINATED

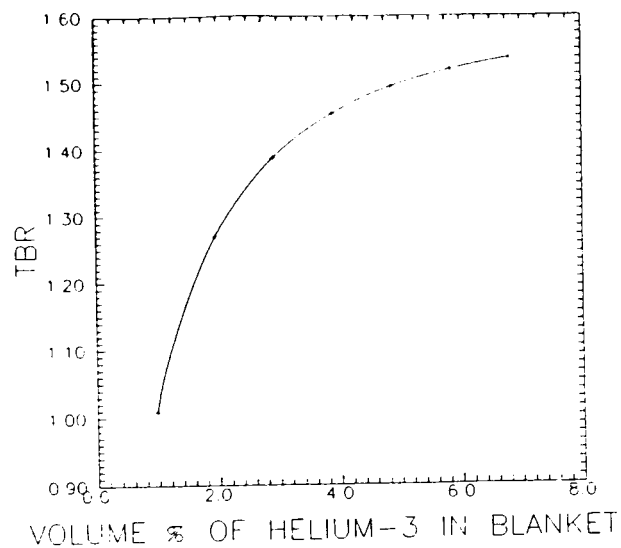
A REFERENCE CONFIGURATION WAS ADOPTED BASED ON MINOR MODIFICATIONS TO THE BCSS He/ LiAlO_2 /Be BLANKET



LiAlO_2 IS REPLACED WITH BERYLLIUM CONTAINING A HELIUM-3 PURGE STREAM



ORIGINAL PAGE IS
OF POOR QUALITY



- THE HELIUM-3 BLANKET EXHIBITS GOOD TRITIUM BREEDING POTENTIAL
- THE REFERENCE CONFIGURATION WAS NOT OPTIMIZED FOR TBR & SOME BREEDING ENHANCEMENT IS EXPECTED

**THE HELIUM-3 BLANKET CONCEPT SHARES
MANY ATTRACTIVE ASPECTS OF He/SB BLANKETS
AND BRINGS SEVERAL ADVANTAGES**

- **COMMON ATTRACTIVE FEATURES**
 - GOOD SAFETY CHARACTERISTICS
 - NO CORROSION CONCERNS
 - GOOD TRITIUM BREEDING POTENTIAL
- **ADVANTAGES OF HELIUM-3 BLANKETS**
 - ONLINE BREEDING CONTROL
 - NOT SENSITIVE TO POWER VARIATIONS &
HEAT CONDUCTANCE CONSTRAINTS
 - REDUCED TRITIUM INVENTORY IN BREEDER
 - NO C-14 PRODUCTION IN BREEDER
- The R & D REQUIRED FOR THE HELIUM-3 BLANKET
WOULD BE SIMILAR TO THAT OF He/SB BLANKETS
WITH EXCEPTION OF SB DEVELOPMENT

TRITIUM CONTROL ISSUES IN ESECOM REFERENCE CASES

Case	Active Tritium Inventory (g)	Dominant Location of Tritium	Difficulty of Control
V-Li/TOK	500	Coolant/breeder	Low
RAF-He/TOK	160	Breeder	Low to medium
RAF-PbLi/RFP	60	Coolant	Medium to high
V-Li/RFP	500	Coolant/breeder	Low
SiC-He/TOK	160	Breeder	Low to medium
V-Flibe/TOK	15	Structure	Medium
V-MHD/TOK	Not estimated	Structure?	Medium?
V-D ³ He/TOK	60	Coolant	Low to medium
RAF-Li/HYB	1000	Coolant/breeder	Low
SS-He/HYB	200	Structure	Low to medium

T/He3 Inventory and Leakage

- Purge circuit He3 volume:
 - Blanket/plenum - 10 m3
 - Piping/T system/misc - 5 m3
- Inventories:
 - He4 coolant - 2000 kg
 - He3 purge - 50 kg
 - T in purge - 0.06 g
 - T in coolant - 0.8 g
 - T in Be - 0.5-1000 g (?)
- Assume 1% circuit leakage/yr (BCSS):
 - He4 - 2 kg/yr
 - He3 - 0.5 kg/yr
 - T - 100 Ci/yr (+ 10 Ci/d across HX)
- Options for He3 inventory reduction:
 - Breeding in outboard only - 25% less
 - Purge flow rate to 30 m/s - 10% less

HELIUM-3 REQUIREMENTS FOR FUSION

	<u>ITER</u> ^a	<u>COMM</u> ^a	<u>100 x COMM</u>
INVENTORY, kg	50	50	5000
LEAKAGE, kg/yr	0.5	0.5	50
BURNUP, kg/yr	8	96	9600
LIFETIME, kg	85 (10 yrs)	3800 (40 yrs)	10 ^c (120 yrs)
COST, \$/g	700 (MOUND)	100-500 (TARGET)	100-500 (TARGET)

^a 600 MW, / 25 % AVAILABILITY

^c 2400 MW, / 75 % AVAILABILITY

**RESERVES OF HELIUM-3 THAT COULD BE
AVAILABLE IN THE YEAR 2000**

SOURCE	CUMULATIVE AMOUNT TO YEAR 2000 (kg)	PRODUCTION RATE POST YEAR 2000 (kg/yr)
Decay of T, DOE		
MRC annual sales	—	1.3
MRC inventory	> 13.4	—
CANDU reactors	10	2
US weapons (approximate)	α 300	α 15
Natural gas wells		
underground storage	29	—
Known reserves	187	—
Total	500 to 600	α 18

Note: Data from the University of Wisconsin (Fusion Technology)

- THE DECAY OF TRITIUM IN MILITARY STOCKPILES
COULD SATISFY THE HELIUM-3 REQUIREMENTS OF
ITER
- COMMERCIAL FUSION POWER WOULD REQUIRE
EXTRATERRESTRIAL SUPPLIES OF HELIUM-3

CONCLUDING REMARKS

- HELIUM-3 BLANKETS OFFERS CONSIDERABLE
PROMISE FOR TRITIUM BREEDING IN FUSION
REACTORS
 - GOOD BREEDING POTENTIAL
 - LOW OPERATIONAL RISK
 - ATTRACTIVE SAFETY FEATURES
- AVAILABILITY OF HELIUM-3 RESOURCES
IS THE KEY ISSUE FOR THIS CONCEPT
 - THERE IS SUFFICIENT HELIUM-3 FROM DECAY
OF MILITARY STOCKPILES TO MEET ITER NEEDS
 - EXTRATERRESTRIAL SOURCES OF HELIUM-3
WOULD BE REQUIRED FOR A FUSION POWER
ECONOMY
 - α 100 - 500 \$/g
 - α 10⁶ kg/yr & α 10⁶ kg